



A new WMO Guide for the Measurement of Cryospheric Variables

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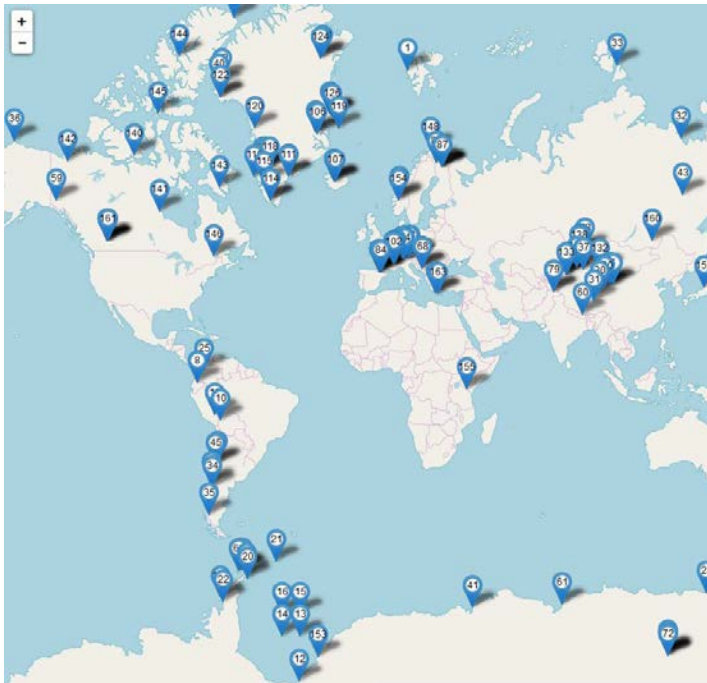


Canada 

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Cryosphere: collective components of the earth's ecosystem that contain frozen water for at least part of the year

Global Cryosphere Watch: WMO cross-cutting initiative for supporting cryospheric observations by providing authoritative, clear, and usable data, information, and analysis on the past, current, and future state of the cryosphere (<https://globalcryospherewatch.org>)



CryoNet: Core of the GCW surface observing network (163 stations) committed to providing high quality cryospheric observations:

Solid Precipitation, Snow, Glaciers and Ice Caps, Ice Sheets, Ice Shelves, Icebergs, Sea Ice, Lake and River Ice, Permafrost, Seasonally Frozen Ground

Motivation for a new best practices guide

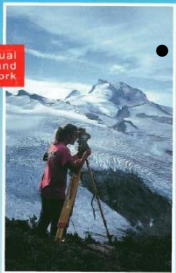
- CryoNet needs a guide to recommend best practices and standardize cryospheric observations
- Currently used guidance for measuring the cryosphere
 - Documents compiled by international organizations
 - CIMO Guide to Meteorological Instruments and Methods of Observation, CHy Guide to Hydrological Practices (WMO)
 - International Classification for Seasonal Snow on the Ground (IACS-UNESCO)
 - Published literature
 - Handbook of Snow (Gray & Male, 1981)
 - Glacier Mass Balance Measurements (Østrem G. & Brugman, 1991)
 - Field Techniques for Sea Ice Research (Eicken et al., 2010)
- Best practices recommendations are often fragmented, cross referenced, outdated, and sometimes nonexistent

Guide to Meteorological Instruments and
Methods of Observation

2014 edition

GLIM MASS-BALANCE MEASUREMENTS

A manual
for field and
office work



G. Østrem and M. Brugman

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Requirements for a new Guide

- Include “recommended” cryospheric variables as defined by GCW
(https://globalcryospherewatch.org/cryonet/variables/recommended_variables.html)
- As much as possible in one place
- Meets the requirements of both the operational and research communities
- Include multiple measurement techniques, both manual and automated
- Updated on a regular basis as methods and technologies evolve





Linkages and Synergies



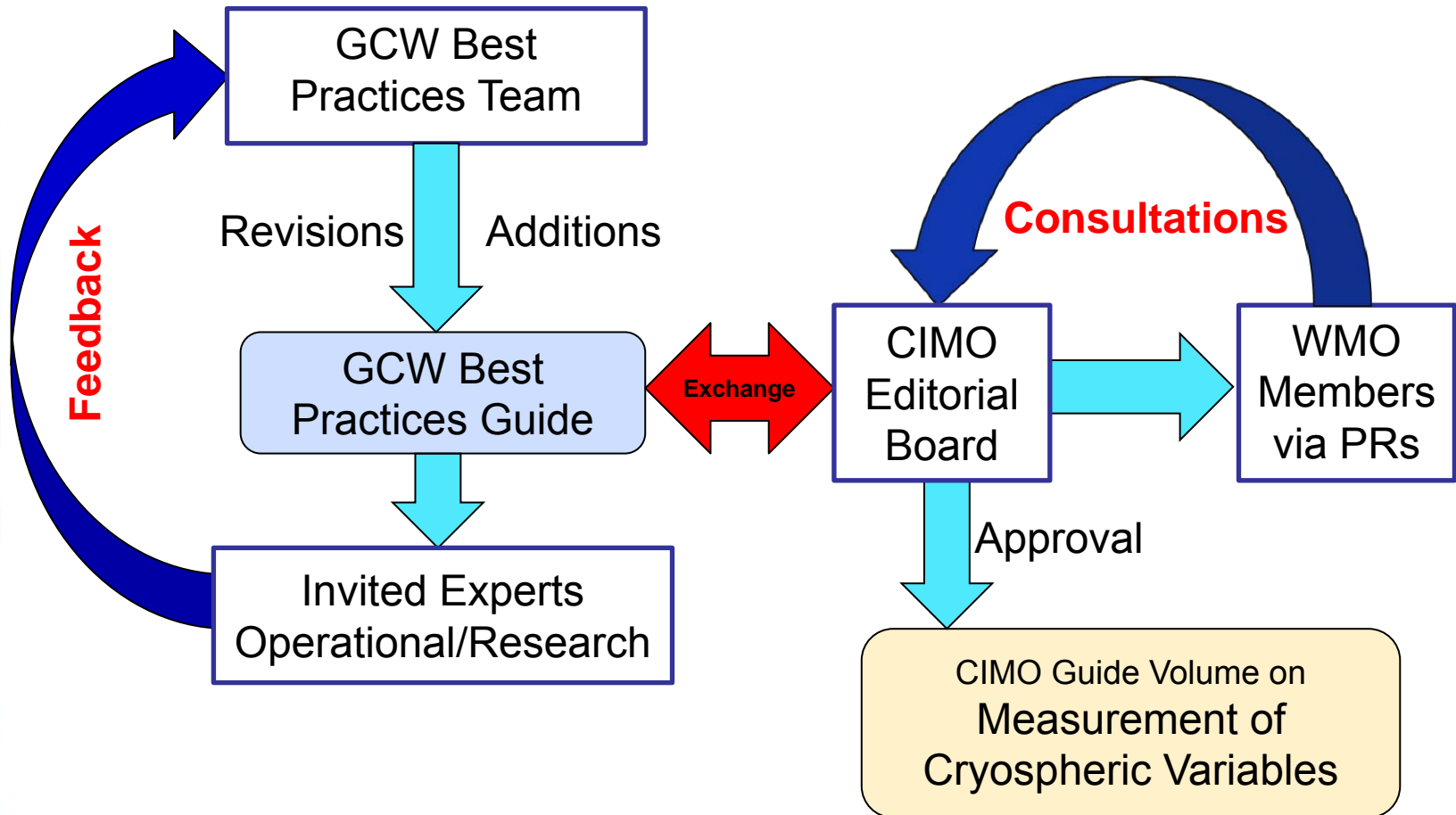
- Integration of cryospheric variables into WIGOS
- Engagement of both the operational and research communities
- CIMO-17 Draft Resolution 3.2(7)/1: increased collaboration between CIMO and GCW, including the delivery of new guidance material on the measurement of cryospheric variables → 2018 Edition of the CIMO Guide (WMO-No. 8)
- First additions to the CIMO Guide Volume on the “Measurement of Cryospheric Variables” is a chapter on **Snow** compiled by the GCW Best Practices Team, incorporating the results of **WMO-SPICE (Solid Precipitation Inter-Comparison Experiment)**
- Updates of the new volume will take advantage of the CIMO editorial process



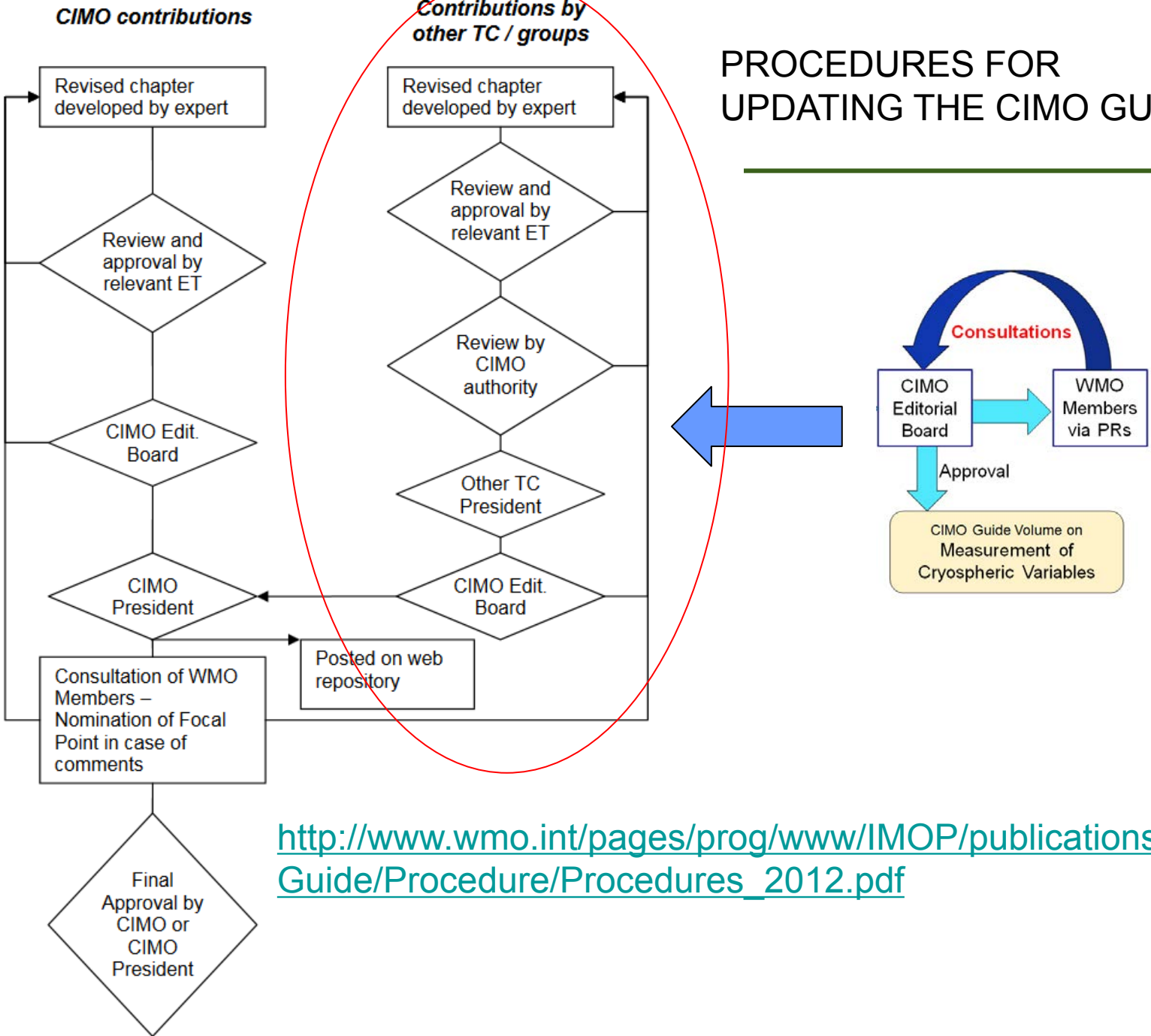
Linkages and Synergies



Guide Development and Updates



PROCEDURES FOR UPDATING THE CIMO GUIDE



http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Procedure/Procedures_2012.pdf

Format and Content

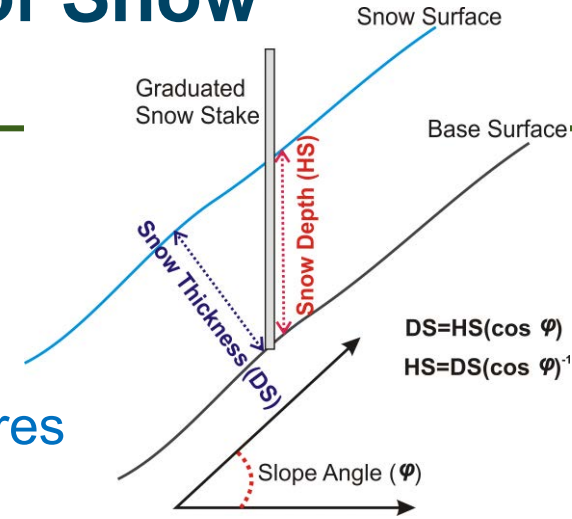
- Similar structure to the current CIMO Guide

Chapter	Title	Progress
1	General*	Under Review
2	Snow*	Under Review
3	Glaciers and Ice Caps*	In Progress
4	Ice Sheets	TBD
5	Ice Shelves	TBD
6	Sea Ice*	In Progress
7	Lake and River Ice	TBD
8	Permafrost and Seasonally Frozen Ground	TBD

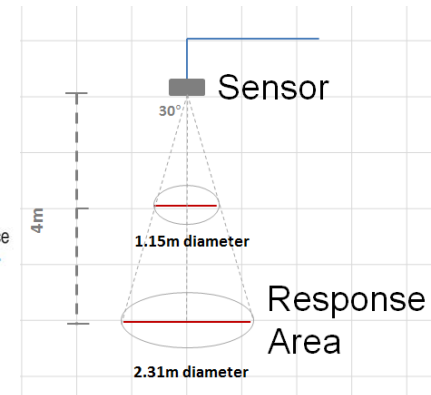
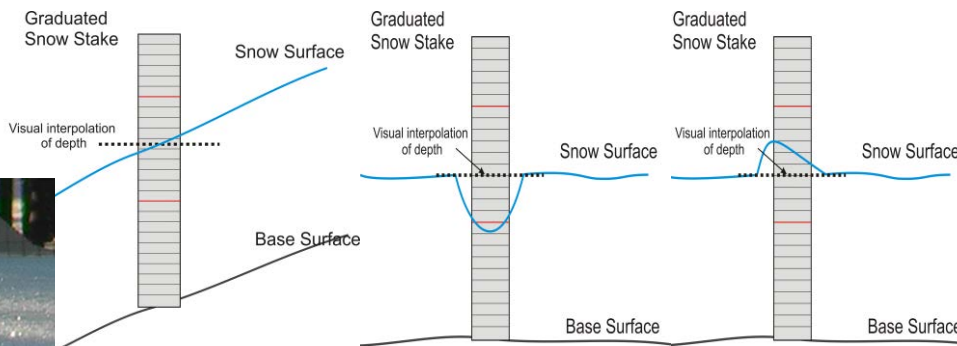
*most advanced

Chapter 2. Measurement of Snow

- Definitions, units, and scales
- Siting and exposure
- Common measurement techniques, procedures and best practices, and sources of error



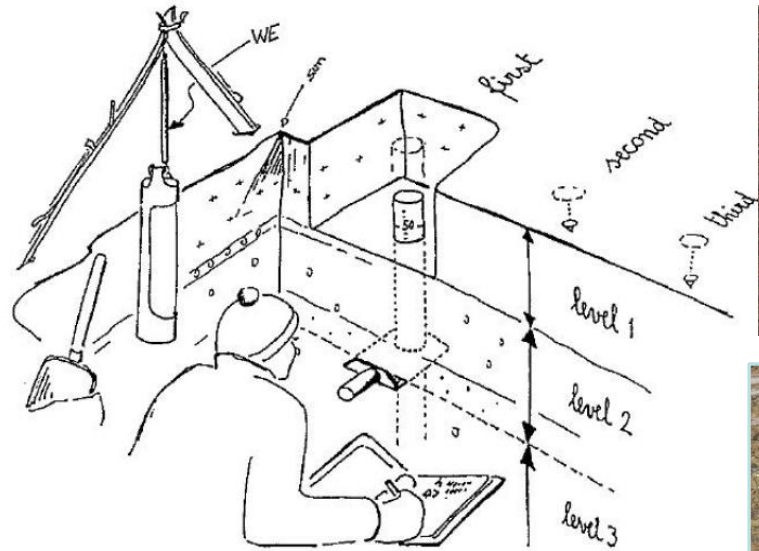
- Snow depth (HS), Water equivalent of snow cover (SWE), Snow properties, Depth of snowfall (HN), Presence of snow on the ground (PSG)
- **Manual** and **Automated** measurements



- Snow chapter to include subtleties of measuring snow on other cryospheric components



Chapter 2. Measurement of Snow



Courtesy G. Kappenberger, SLF



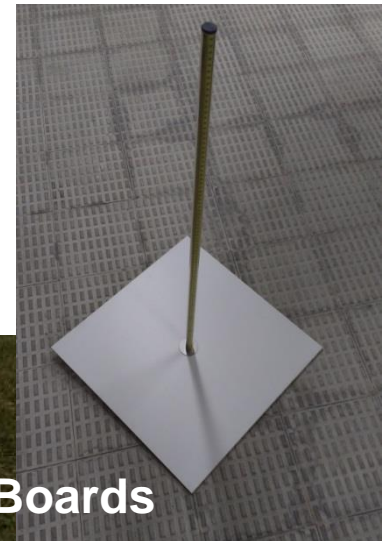
ESC-30 Snow Tube



Snow Scale



Snow Boards

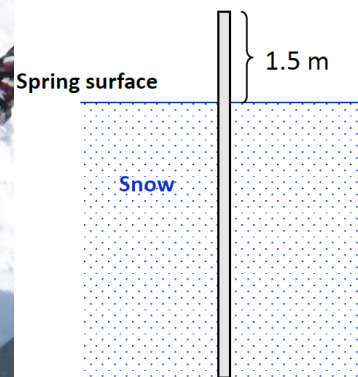


Chapter 3. Glaciers and Ice Caps

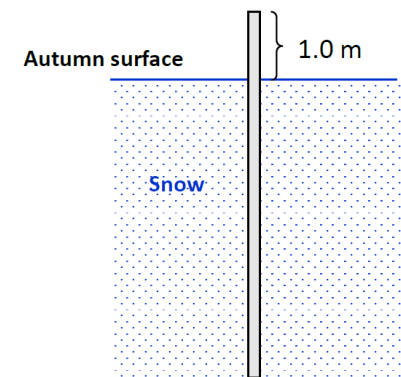
- Defining, characterizing, and classifying glaciers and ice caps
- Standard/Classic methods and emerging technologies → need for calibration-validation to ensure consistency and continuity
- Glacial outlines and areas, thickness and volume, mass balance (stake vs. DEM-differencing), surface accumulation/ablation, surface mass balance, basal ablation, calving flux, glacial runoff, ice velocity (stake vs. GPS), ice/firn temperature profiles



Snow coring



Spring



Autumn

Borehole stakes in accumulation area

Chapter 6. Sea Ice

- Remote sensing is the primary source of data for ice monitoring but relies on in situ, coastal, shipborne, and airborne measurements
- Ice thickness, concentration, freeboard, stage of melting, class (pack or fast ice), type of pack ice (level, rafted, ridged, etc)
- “Derived” parameters: stage of development, start day of melt, duration of ice cover

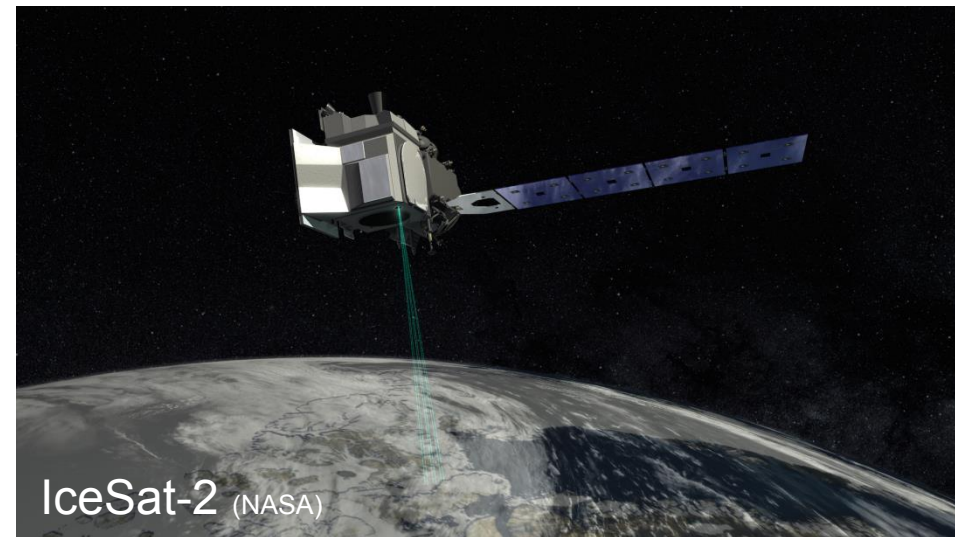


Chapter 6. Sea Ice

Antarctic Fast-Ice Network (AFIN)	Parameter	Observation frequency
Thickness transect	Z_{ice} , Z_{snow} , FB, growth rate	days–weeks
Mass-balance station	Z_{ice} , Z_{snow} , T_{ice} , T_{snow} , T_{air} , P_{air}	10 min
Digital imaging	Ice presence, ice extent and point, breakout	10 min
Weather station	T_{air} , P_{air} , Wind velocity, Relative humidity	10 min
Remote sensing	Ice extent, lead pattern, outer pack and point	hours to days
Structural ice cores	Ice structure, T_{ice} , vertical salinity profile	annual



Davis CryoNet Fast-Ice Site (AAD)



IceSat-2 (NASA)



Path Forward

- Chapters 1 (General) and 2 (Snow) currently undergoing parallel reviews from both CIMO members and GCW invited experts
- Chapters 3 (Glaciers) and 6 (Sea Ice) being incorporated this fall
- GCW engaging experts for remaining chapters (Permafrost, Lake and River Ice, Ice Sheets, Ice Shelves)
- Completion expected by 2020
- GCW recommended cryospheric variables integrated into WIGOS
- Potential supplementary material: online schematics and photos, “how to” videos on a YouTube channel





Thank You